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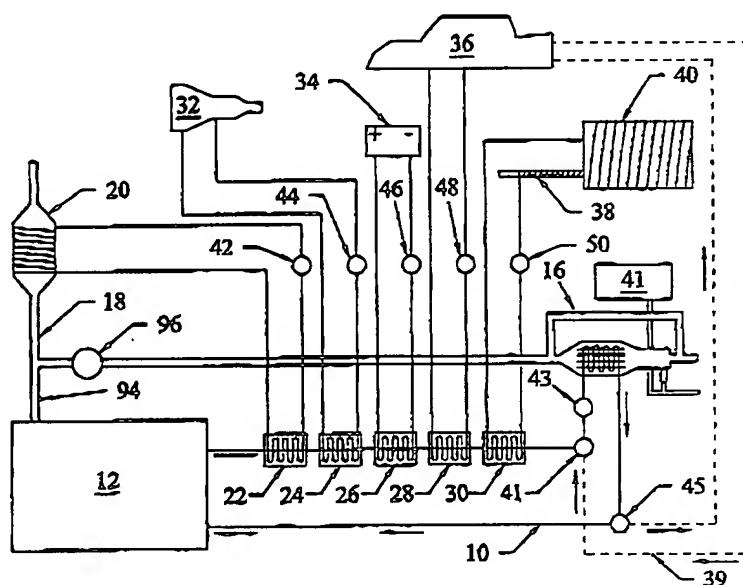
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(54) Title: THERMAL MANAGEMENT OF ENGINES



(57) Abstract: Associated with an internal combustion engine (12) is a pre-heat unit (16) that is operable independently of the engine (12) for pre-heating the engine (12) through its cooling system (10) and/or its lubricant system. The pre-heat (16) may be used to pre-heat auxiliary systems, such as vehicle fluid systems, battery (34), passenger compartment (36), etc.

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storage provided by the battery. The energy storage capacity of the battery is very limited and insufficient to meaningfully warm a cold engine. The energy density of typical fuel is very large compared to that of current battery technology (on the order of two orders of magnitude larger). As a result, electrical pre-heaters have been
5 limited to very local pre-heating applications, such as glow plugs in Diesel engines and some pre-production, electrically-heated catalytic converters.

Despite the rather local nature of these pre-heating strategies, electrical powers of the order of 0.5 to 1 kW are used (which represents large currents of the order of 40 to 80 amperes from standard 12-volt battery systems) for relatively short time (15 sec. to
10 a minute). By comparison, the power required to provide a significant shortening of the thermal transients of larger systems such as the entire powertrain are several orders of magnitude larger, making it virtually impossible by electrical means.

This leads to the concept of a burner capable of utilizing the chemical energy of the main fuel supply of the vehicle. However, this burner must be able to easily and
15 reliably start under cold conditions and burn very cleanly to avoid adversely affecting the vehicle emissions, while also being very light weight and compact for easy integration with a vehicular platform. In the case of the energy efficient vehicles, the fuel supply is likely to be Diesel fuel, which is characterized by very low volatility and poor ignition characteristics. The present invention is directed to such a burner
20 and its incorporation into an internal combustion engine system.

U.S. Patent No. 5,735,238 describes a thermal management system for internal combustion engines in which exhaust heat is used efficiently to heat the engine. While efficiencies may be achieved, a cold start-up is still required.

U.S. Patent No. 5,867,987 describes an engine having a turbocharger in which
25 exhaust gases are used for heating the engine during warm-up.

U.S. Patent No. 3,892,213 describes a further system for utilizing exhaust gases for engine warm-up.

U.S. Patent No. 5,444,978 describes a method of providing an air stream and electric heat to a catalytic converter so that the converter is more efficient during
30 vehicle warm-up.

U.S. Patent No. 4,088,109 describes a system for heating glow-plugs during engine warm-up.

In very cold climates, it is common to keep vehicles, particularly diesel powered vehicles, running even when not in use because re-starting of the vehicle

would be difficult or impossible once the vehicle's engine and other components equilibrate to the cold ambient temperature. The present invention may, in many cases, obviate the need for continuous operation of a vehicle's engine, thereby resulting in very significant fuel savings and accompanying reduction in vehicle emissions.

Summary of the Invention:

In accordance with the present invention there is provided a small, but powerful burner unit which is activated independently of the engine and is used primarily to pre-heat the engine block, for example through circulation of engine coolant through the burner unit. The burner unit burns a fuel that is preferably the primary fuel by which the engine operates, be it gasoline, diesel fuel, ethanol, or any other engine fuel. Secondly, the heat from the burner unit heats other systems that benefit in efficiency or operability from pre-heating, including the catalytic converter, battery, transmission, and, in the case of diesel fuel, the fuel line and fuel tank. Also, the heat can be used to pre-heat the passenger compartment of the vehicle.

Brief Description of the Drawings:

Figure 1 is a diagrammatic illustration of an automotive pre-heating system utilizing a pre-heat burner unit in accordance with the present invention

Figure 2 is a cross-sectional view of the pre-heat burner unit in accordance with the present invention.

Figure 3 is an enlarged cross-sectional view of the atomizer unit used to provide atomized fuel to the burner unit in accordance with the invention.

Figure 4 is a diagrammatic illustration of a heating system utilizing the burner unit of the present invention.

Figure 5 is a graph showing Thermal Transient Results from an AdvisorTM vehicle simulator during cold-start FUDS cycle.

Figures 6a and 6b are graphs showing, respectively, fuel economy and hydrocarbon emissions at different initial temperatures and burner heat inputs.

Figures 7a, 7b, and 7c are graphs showing, respectively, Co, particulate and NO_x emissions at different initial temperatures and burner heat inputs.

Detailed Description of Certain Preferred Embodiments:

In accordance with the invention, a small, but powerful and fuel efficient burner unit 16 is provided in the engine compartment of an automobile for the primary purpose of pre-heating the engine. In the diagrammatic illustration of Figure

1, this is done through the engine coolant system 10 in which coolant is circulated from the engine block 12 by a pump 43 and to the burner unit 16 of the present invention. Alternatively, the pre-heating could be done through the engine oil system by pre-heating the engine oil and circulating the pre-heated oil through the engine.

5 Or both engine coolant and engine oil could be pre-heated. The exhaust from the burner unit 16, which burns very cleanly, exits through the vehicle exhaust system 18 helping to pre-heat the catalytic converter 20 to a temperature whereat it acts efficiently to reduce hydrocarbon emissions once the engine is turned on.

It is to be appreciated that the flame of the burner unit 16 is fully contained within the heater housing of the unit. Accordingly, if the burner is appropriately placed within the engine compartment there is substantially no danger of the burner causing an engine fire.

The burner unit 16 is designed to operate using the fuel from the vehicle fuel tank 40. Because the burner unit 16, as described in greater detail hereinbelow, uses an atomizing system that produces a very fine aerosol of any conventional fuel, including diesel fuel, and provides for very efficient burning of such atomized fuel, there is no need for an independent fuel source. Of course, a secondary fuel tank could be provided solely for operation of the burner, but this would involve additional expense and complexity.

20 Because the burner unit 16 is designed to burn very efficiently, it produces very little carbon monoxide, and any carbon monoxide produced will be substantially completely oxidized to carbon dioxide in the catalytic converter, even during warm-up of the catalytic converter as the total emission level from the burner unit 16 is very low. Accordingly, the system may be operated even in a closed garage for pre-heat without endangering persons. Pre-heater units 16 in trucks might be operated on a schedule controlled by a remote timer unit. Preheating of commercial vehicles might be mandated for reasons of fuel efficiency and emissions reductions. Individuals might be motivated to pre-heat their vehicles either by reduced fuel usage and/or the comfort and convenience of entering a pre-heated vehicle. Such motivation would be strongest in cold weather where the greatest efficiencies afforded by the pre-heat system are realized. This would be especially convenient if a remote, burner unit activation system is employed.

30 The diagrammatic illustration of Figure 1 also shows secondary heat exchangers 22, 24, 26, 28, and 30 by which heat is transmitted to various other

automotive systems which benefit from pre-heating, including the catalytic converter 20, the transmission system 32, the battery compartment 34, the passenger compartment 36, and the fuel system including the fuel line 38 and fuel tank 40. Fluid flow from the secondary heat exchangers 22, 24, 26, 28 and 30 is controlled by pumps 42, 44, 46, 48 and 50, respectively. These listed secondary systems each benefit in important ways from pre-heating, but it is appreciated that additional automotive systems can benefit from pre-heating as well. The catalytic converter 20, the battery 34, and transmission 32 are each known to operate more efficiently at warm, rather than cold conditions. Although the catalytic converter is partially heated by exhaust gases from the burner unit 16, additional heat from heat exchanger 22 assists in bringing the converter up to peak operating conditions even more rapidly. Instead of secondary heat-exchangers, the secondary systems may be linked directly to the primary coolant system by secondary recirculating lines connected to the primary coolant line, and flow through these secondary lines may be controlled by valves.

The passenger compartment 36 is desirably pre-heated for comfort. Such comfort may encourage use of the pre-heat burner unit of the present invention by those not mandated to use the pre-heat system. The pre-heat system might, for example, be remotely activated, such that individual automobile owners will activate their pre-heat systems on cold days if for no other reason than to climb into a warm automobile. Electrically operated systems, such as the defrost fan might be operated for short periods of pre-heat without substantial drain of the battery. Battery driven pre-heat may still be used for pre-heating small components, such as diesel glow plugs.

With respect to heating the passenger compartment, illustrated in dotted lines is an auxiliary line 39 running to the passenger compartment 36 for heating the passenger compartment only in emergency situations, such as a disabled car in a blizzard. Valves 41 and 45 send the entire heat output of the burner unit 16 to the passenger compartment 36 in such emergencies, other than that which is exhausted. Because the passenger compartment uses substantially less heat than is needed to pre-heat an engine, the burner unit 16 and pump 43 may operate intermittently during these periods, thereby extending heating of the passenger compartment for a substantial length of time. Because a relatively small amount of fuel is burned during

such emergencies, the catalytic converter 20 can very readily handle all emissions such that the occupants are not subject to meaningful levels of carbon monoxide.

In very cold temperatures, diesel fuel tends to gel; accordingly, preheating of the fuel line 38 and fuel tank 40 may be used to reduce the viscosity of the fuel. In such very cold conditions, diesel engines are often left running even when the vehicle is not moving because re-starting a cold vehicle may prove to be difficult or even impossible. With the pre-heat unit 16 of the present invention, it may be practical to de-activate diesel engines when the vehicle is not used and subsequently re-start the engine. In addition to the above-described fuel savings and emission reductions, substantial additional fuel savings and emission reductions may be realized if the vehicle can be shut off and then restarted. If re-starting of a very cold diesel engine is a contemplated use of the burner unit 16 of the present invention, it may be desirable that the vehicle carry a small additional tank 41 of a fuel that is lighter than diesel fuel to operate in the pre-heat unit. A small tank 41 of gasoline, ethanol, or other light fuel could serve such purpose.

In gasoline engines, preheating of the fuel line and fuel tank is generally not necessary, and means for heating these components would not be present.

Thermal sensors (not shown) associated with feed-back mechanisms (not shown) may be used to control pumps 42, 44, 46, 48 and 50 to prevent overheating of any individual system. Likewise, thermal sensors already in the engine coolant system may be used to de-activate the burner unit 16 of the present invention after the engine block has been sufficiently heated and to re-activate the burner unit should an extended period of engine cooling transpire between de-activation and actual start-up of the engine. It should also be understood that heating of the primary coolant may require a bypass of the thermostat on the engine block, to allow coolant flow. Other modifications may be necessary, all of which are deemed to be within the skill level of an ordinary automotive mechanic.

Other heat exchange loops could be used to pre-heat a variety of automotive systems. Almost any fluid system, including brake fluid, power steering fluid, washing fluids, etc. can benefit to one extent or another from pre-heating.

The burner unit 16 is designed, generally, to operate on the fuel that is used to run the vehicle's engine, utilizing fuel from the vehicle's fuel tank. This fuel includes both gasoline and diesel fuel or any other fuel which may be used in an internal combustion engine. Although the burner uses fuel, the net fuel use, as a consequence

of almost immediate peaking of efficiency of the engine, once started, is reduced. Also, the burner can burn very efficiently with low emissions, and the reduced emissions of the pre-heated engine results in very substantial net reductions of vehicle emissions. Also contributing to net reduction of emissions is pre-heating of the catalytic converter to efficient operating temperatures.

The burner unit 16 is illustrated in greater detail in Figure 2. A housing 70 includes an upstream gas mixing region 72, a combustion region 74, and a heat exchange region 76. Air is introduced into the gas mixing region 74, which in the illustrated embodiment is introduced at an upstream end 73 of the mixing chamber. Slightly downstream, an atomizer unit 80 introduces a spray of finely atomized fuel 82. The air and fuel mix in the mixing region 72. To promote additional mixing, a fine grate 84 is provided at the downstream end of the mixing chamber 72. Just downstream of the grate 84, at the entrance to the combustion chamber 74, is a flame-controlling metal mesh 86. The flame 88 is produced at this point. Combustion is initiated by device 90 that may be, for example, by a resistive electrical element or spark gap that operates from the vehicle battery, or a pilot flame. The tips of the flames 88 stop short of the end of the combustion region 74, and hot gases flow to the heat exchange region 76.

Through the heat exchange region 76 run coils 89 which are part of the engine coolant loop 10. Closely spaced metal foils 90 assist in the transfer of heat to the coils 88. The gases then exit conduit 92 that interconnects to the engine exhaust 94 where the exhaust gases of the pre-heat unit 16 assist in pre-heating of the catalytic converter. A valve 96 may be employed to prevent exhaust gases from the engine from backing into the pre-heat unit when the engine is running and the pre-heat unit 16 deactivated. An optional conduit 93 returns a small portion of the pre-heat exhaust gas to mix with and thereby pre-heat the inlet air stream. It is found that such pre-heating reduces NO_x emissions.

An important aspect of the pre-heat unit 16 is the atomizer 80 that produces a fine aerosol of the fuel that is burned in the unit. Shown in greater detail in Figure 3, atomizer 80 includes a housing 100 having an inlet end 102 and an outlet end 104. The housing contains an electrode 110 that is insulated from the housing by an insulative sleeve 114. A tubular restriction 118 extends from electrode 110 to the inlet end 102 of the housing 100. A second insulative sleeve 112 surrounds the coils of tubular restriction 118 to insulate the tube from the housing 100. Battery power

from the vehicle is applied between the housing 100 and electrode 110 to internally heat the fuel within tubular restriction 118 by passing current through the resistive material that comprises tubular restriction 118. The outlet end 104 of the housing has an end cap 106 to allow the tube 11, electrode 110, insulative sleeves 112 and 114 as well as spacer 116 to be removed from the housing 100. In operation, fuel is pumped under pressure through an inlet end 102 of the housing 100 of the atomizer 80. The fuel is heated as it flows through tubular restriction 118 (the coils extend the length of the tubular restriction 118, thereby increasing heating time of the fuel). Heated, pressurized fuel flows out of outlet end 104 (through a bore in end cap 106) and into the mixing region 72 of the pre-heat burner unit which is of lower pressure and lower temperature. The fluid leaving the atomizer 80 atomizes into fine droplets. The size of the droplets can be determined by the temperature of the fuel as it passes through the tubular restriction, which, in turn, is controlled by the electrical energy provided between the electrode and housing. In fact very fine tuning of droplet size can be achieved. To provide efficient mixing with air and therefore very efficient burning, it is preferred that the average droplet size produced by the atomizer be about 5 microns in diameter or less, preferably about 1 micron in diameter or less. Because of the small droplet size produced by the atomizer 80, the pre-heater can operated very lean, i.e., with just a slight excess of oxygen relative to stoichiometric amounts to fully oxidize the fuel.

While the invention has been discussed herein primarily in terms of automotive engines and vehicles, the invention is not limited to automotive applications. Boat engines, or electrical generator engines, might similarly benefit from a pre-heater in accordance with the present invention.

The systems for heating systems auxiliary to the engine are not optimized, and heating of such auxiliary systems is expected to be more finely engineered to achieve optimal thermal efficiencies. A wide variation of heat transfer systems may be adapted to particular vehicular requirements.

Although the invention has been described herein with respect to internal combustion engines, pre-heating could assist other types of engines and systems. In hybrid engines, relying for power in significant part on storage batteries, the pre-heating will provide additional benefits by heating the storage batteries. In proposed fuel cell powered vehicles, pre-heating of the battery of fuel cells will reduce the time needed to bring them up to optimal efficiency. Fuel cells may be directly heated, or

the gases, particularly hydrogen and air supplied to the fuel cells may be heated. Figure 4 illustrates burner unit 16 being used to heat systems 150 and 152. The heat exchanger can be used to heat a system as shown with respect to system 152. The fluid used in the heat exchanger may be selected from a large number of gasses and liquids depending on the application. Heat may also be applied to a system (such as 150) by providing heated air from the burner unit 16. Obviously, heat can be supplied to a single system from both the heat exchanger and by heated air. For example, the heat exchanger may provide heated hydrogen, while the burner unit directly supplies heated air to the appropriate regions of a fuel cell. The fuel for the burner unit 16 can be provided from a separate tank 41 or from the same fuel source as used by the heated system (if any).

The invention will now be discussed in greater detail by way of specific example.

Example (simulation testing)

Tests were conducted on the Fiat 2.4 L. JTD diesel engine. The test's purpose was to quantify the thermal behavior of the engine and provide data for simulations. Several engine parameters were monitored, such as the coolant flow rate, coolant temperatures, oil temperatures, exhaust temperature, and fuel consumption. This data allowed for a more complete understanding of the processes and time scales involved in the warm-up process. The data was incorporated into Ohio State University's hybrid vehicle simulator, VP-SIM, to estimate the temperature of the engine over a given driving cycle. The results were then used to validate the result of another hybrid vehicle simulator, ADVISOR™, developed by NREL. The ADVISOR™ simulator was then modified to simulate the effects of the burner on the engine's fuel consumption and emissions.

The results are shown below in Figure 5 and the accompanying table below:

		<u>Table</u>		
		<u>Normal</u>	<u>Warm</u>	<u>Decrease</u>
<u>Initial Conditions</u>				
5	Coolant Temp (°C)	20	100	
	Catalyst Temp (°C)	20	150	
<u>Emissions</u>				
	Hydrocarbons			
	(gm/mile)	0.533	0.233	56%
10	CO (gm/mile)	2.147	0.787	63%
	NO _x (gm/mile)	1.89	1.662	12%
	Particle			
	emissions(gm/mile)	0.161	0.07	57%

15 Figure 5 shows that a thermal transient for the catalytic converter is on the order of 3 minutes and a thermal transients for the engine coolant of the order of 10 minutes. Similarly the reduction of emissions shown in the table provide a clear indication of the large effect of the cold-start transient on emissions.

With the modified version of the ADVISORTM simulator several simulations
 20 were conducted to explore the feasibility of the project. Results of simulations are presented in Figures 6a, 6b, 7a, 7b, and 7c for three different starting temperatures 0, 10 and 20° C for various burner heat inputs. These figures show how the burner unit of the present invention effects fuel economy and emissions at different initial temperatures and burner heat levels. Figure 6a shows the increase in fuel economy
 25 (shown on the left side in miles/gallon) as a function heat output (shown along the bottom in kW) from the burner unit. Figure 6b shows hydrocarbon emissions in grams/mile as a function of burner heat output. Figure 7a shows CO emissions in grams/mile as a function of burner heat output. Figure 7b shows PM emissions in grams/mile as a function of burner heat output. Figure 7c shows NO_x emissions in
 30 grams/mile as a function of burner heat output. The conclusions of the simulated tests are that:

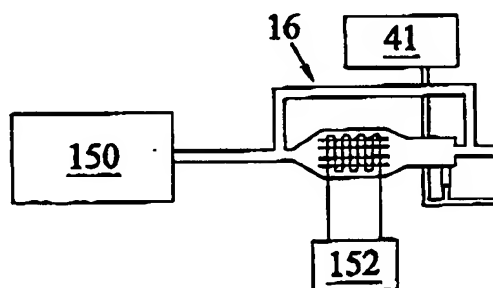
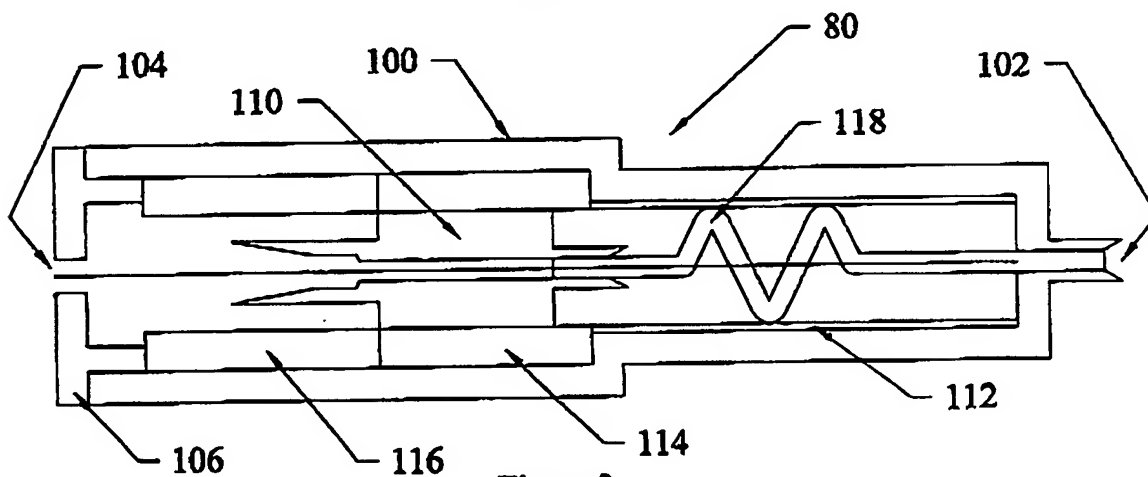
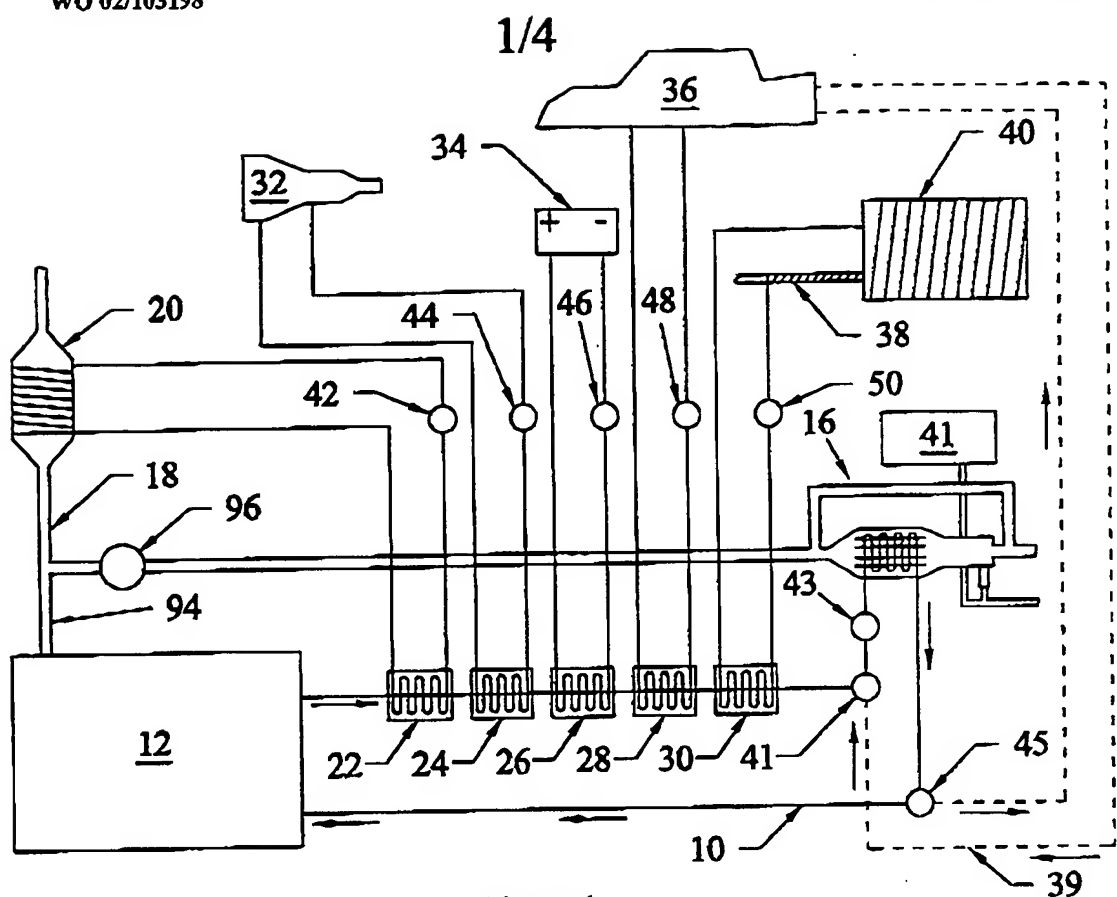
- The burner can both reduce emissions and increase fuel consumption
- Fuel economy increases to a certain level and then begins to decrease with increasing heat input
- 35 • Emissions tend to approach a value asymptotically with increasing heat input.
- The lower the starting temperature, the greater benefits that are achieved with the burner.

What is Claimed is:

1. In combination,
an internal combustion engine having a coolant system and/or a lubrication system,

a fuel supply means for supplying fuel to said engine, and
a fuel-burning burner means external of said engine and operable independently of said engine for heating at least one of said coolant of said coolant system or lubricant of said lubrication system with or without said engine being activated.
2. The combination of Claim 1 wherein said engine has both a coolant system and a lubrication system and said burner means heats both said coolant system and said lubricant system.
3. The combination of Claim 1 comprising a re-circulation loop for conveying at least one of coolant from said coolant system or lubricant from said lubrication system, said re-circulation loop including heat exchange means for transferring heat from said burner means to said re-circulation loop, and pumping means for conveying said coolant or said lubricant through said re-circulation loop.
4. The combination of Claim 1 wherein said burner means burns fuel supplied from said fuel supply means.
5. The combination of Claim 1 further including means for transferring heat from said burner means to auxiliary systems.
6. The combination of Claim 5 wherein said auxiliary systems are selected from the group consisting of a battery, a passenger compartment, transmission fluid, brake fluid, power steering fluid, fuel line, fuel tank, and combinations thereof.
7. The combination of Claim 1 further including a catalytic converter through which engine exhaust is passed to reduce hydrocarbon and carbon monoxide emissions, said burner means having means to exhaust gases through said catalytic converter to preheat the same, whereby said catalytic converter operates with enhanced efficiency upon activation of said engine.

8. In combination,
an engine,
an energy supply means for said engine, and
a fuel-burning burner means external of said engine and operable
independently of said engine for heating at least one of said engine or said
energy supply means with or without said engine being activated.
9. The combination in accordance with Claim 8 wherein said engine is an
electrical engine, said energy supply means comprises a battery of fuel
cells, and said fuel-burning means is operable independently of said engine
for heating said battery of fuel cells.



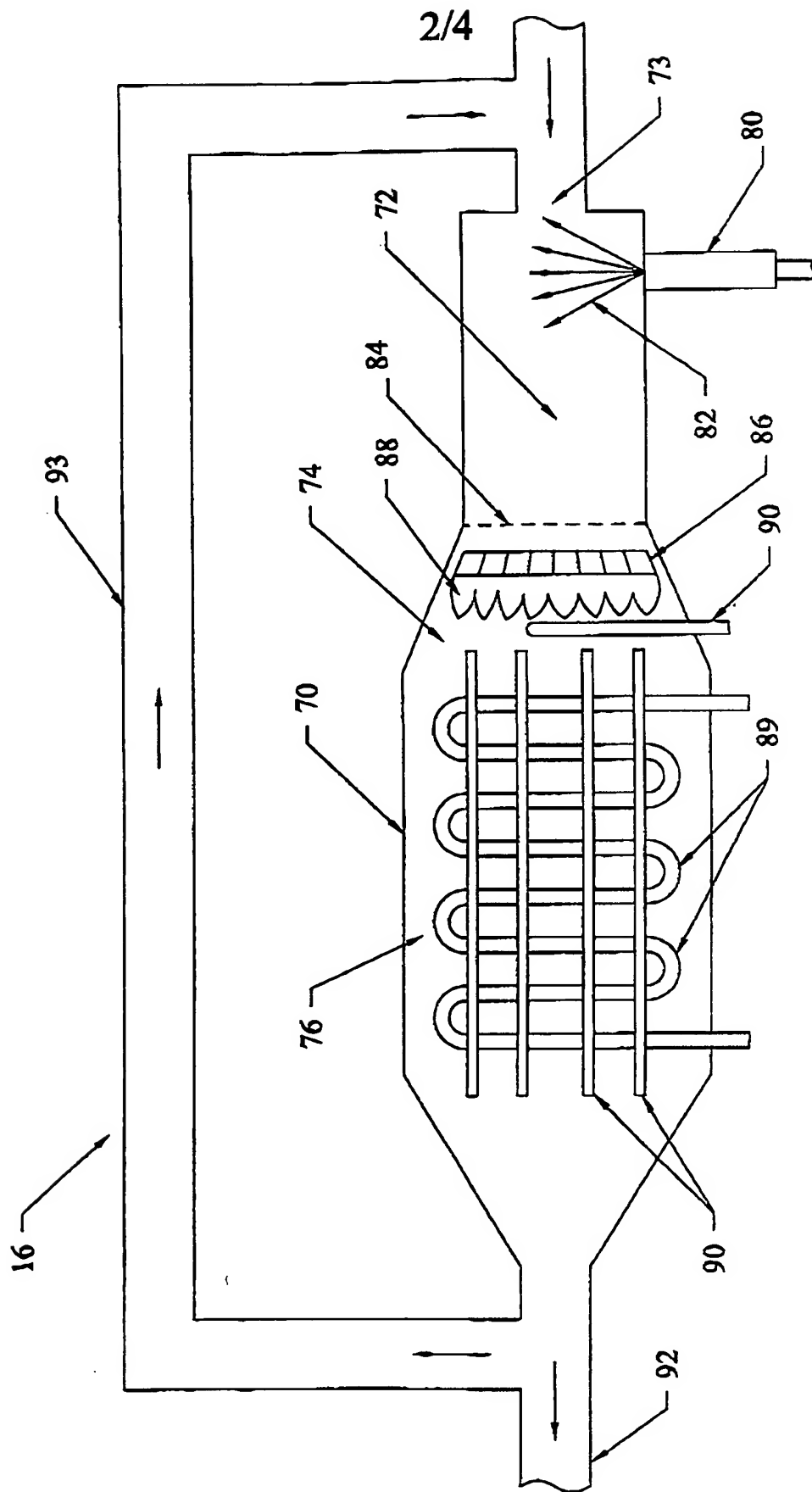


Figure 2

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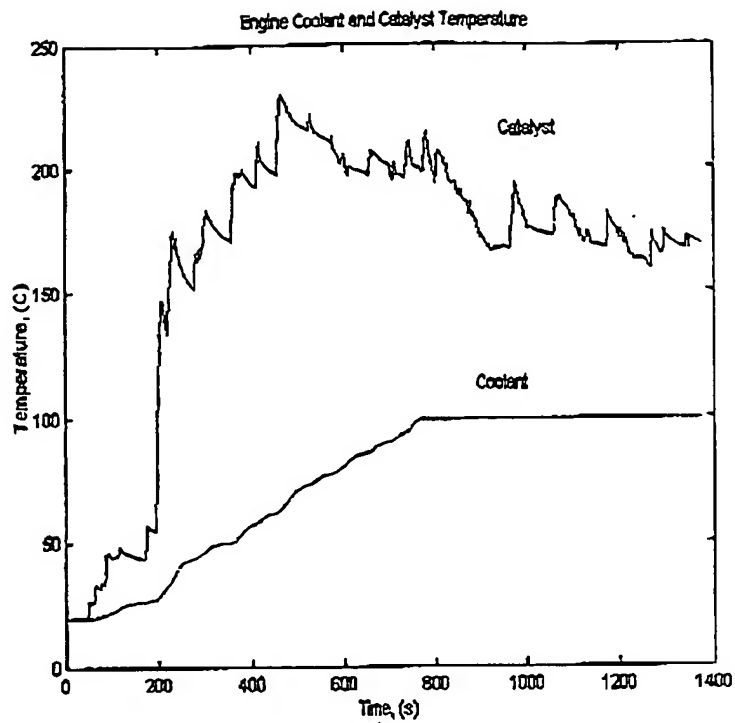


Figure 5

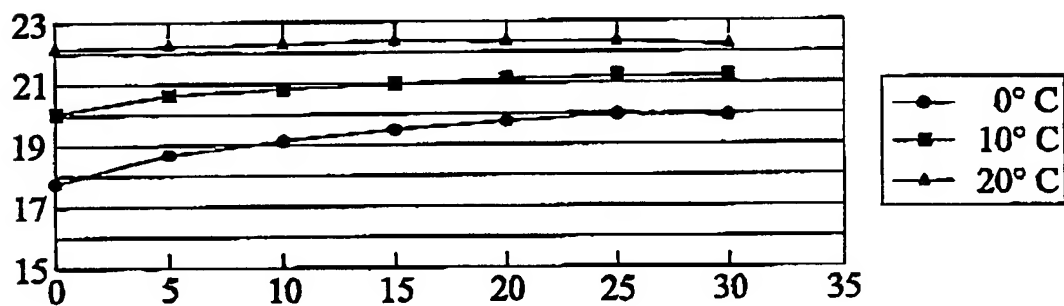


Figure 6a

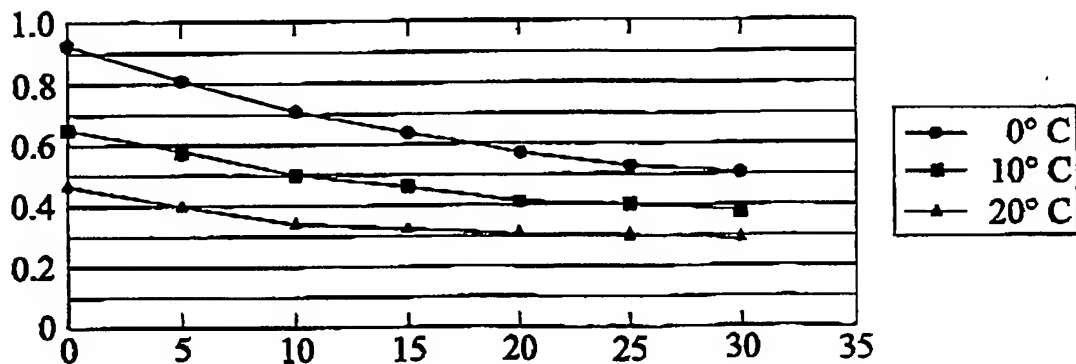


Figure 6b

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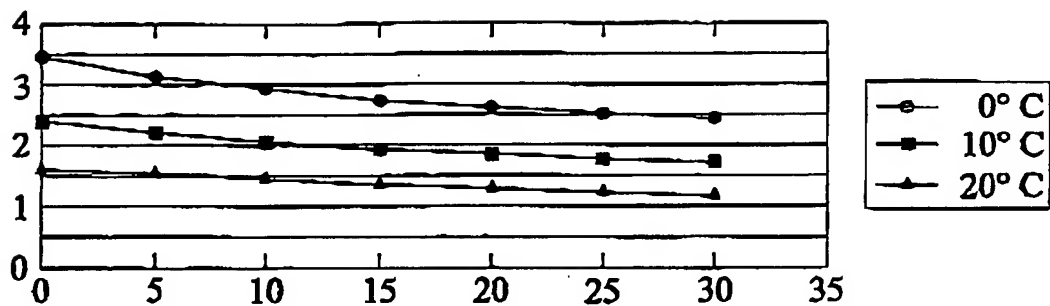


Figure 7a

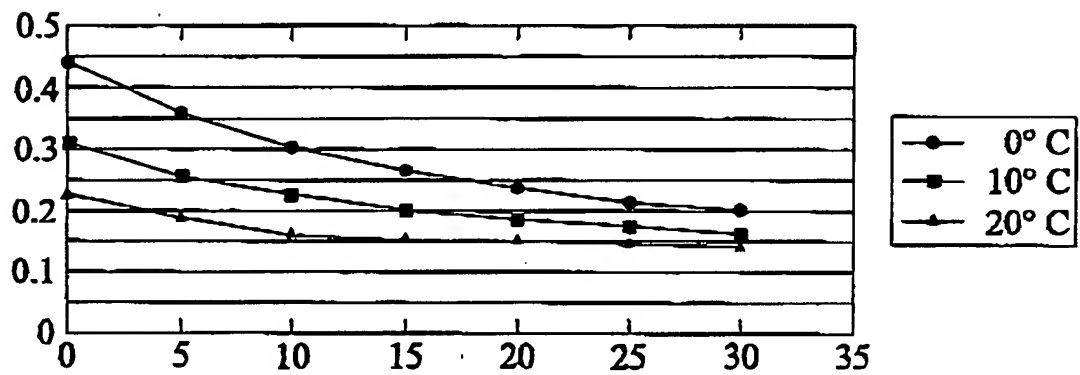


Figure 7b

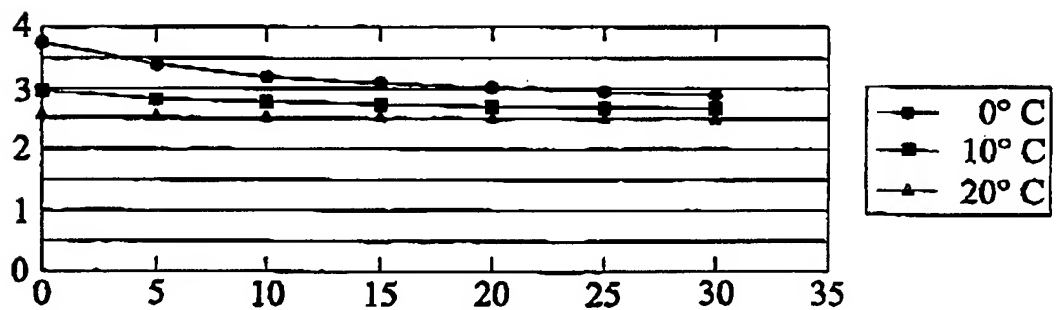


Figure 7c

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/19038

A. CLASSIFICATION OF SUBJECT MATTER IPC(7) : F02N 17/047 US CL : 123/142.5R According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 123/142.5R Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched NONE Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EAST burner, coolant, oil or lubricant		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,047,676 A (TRAPY) 11 April 2000, col 3, lines 10-15, 29-35, 47-53, col 4, lines 57-60	1-8
Y		9
A	US 4,010,725 A (WHITE) 08 March 1977, see entire document	1-9
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"E" earlier documents published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"A" document member of the same patent family	
"O" document referring to an oral disclosure, use, exhibition or other means		
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Date of the actual completion of the international search 28 AUGUST 2002		Date of mailing of the international search report 19 SEP 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 306-3250		Authorized officer <i>J. Husley for</i> MARGUERITE MCMAHON Telephone No. (703) 308-1966

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